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INSTITUTO DE CIÊNCIAS BIOMÉDICAS ABEL SALAZAR
UNIVERSIDADE DO PORTO

Artigo tipo “Case Report”

Mestrado Integrado em Medicina

# Patellofemoral Instability: The Biomechanical Analysis of the Gait

Ângela Isabel Freitas da Fonseca Sampaio

Porto, junho de 2017

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ÂNGELA ISABEL FREITAS DA FONSECA SAMPAIO

# Patellofemoral Instability: The Biomechanical Analysis of the Gait

Artigo tipo "Case Report", submetido ao Instituto de Ciências Biomédicas Abel Salazar, da Universidade do Porto

**Orientador:** Dr. Adélio Justino Machado Vilaça

**Título profissional:** Assistente Hospitalar no Serviço de Ortopedia do Departamento de Ortofisiatria - Hospital Santo António - Centro Hospitalar do Porto
Largo do Prof. Abel Salazar, 4099-001 Porto, Portugal
Assistente Convidado de Ortopedia e Docente Externo do Departamento de Anatomia do Instituto de Ciências Biomédicas Abel Salazar da Universidade do Porto
Rua de Jorge Viterbo Ferreira, nº 228, 4099-313 Porto, Portugal

**Grau académico:** Licenciatura em Medicina

**Afiliação:** Instituto de Ciências Biomédicas Abel Salazar da Universidade do Porto

**INFORMAÇÃO TÉCNICA:**

**TÍTULO:**

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**AUTOR:**

Ângela Isabel Freitas da Fonseca Sampaio

**DATA:**

Junho de 2017

**EDITOR:**

Ângela Isabel Freitas da Fonseca Sampaio

**CORREIO ELETRÓNICO:** samapaio10100238@gmail.com

**1ª EDIÇÃO:** Junho de 2017

## ACKNOWLEDGEMENTS

The realization of a dissertation is a project that, although with individual character, is only possible with the support and contribution of several people. At the end of this long and laborious stage of my academic life, I would like to thank all those who have made this path easier.

To Dr. Adélio Vilaça, to whom I express a special thanks for his guidance, support and knowledge sharing. His availability, the stimulation to the knowledge and the interest for the success of this work made possible its accomplishment in an area that is so dear to me.

To Engineer Pedro, whose work and commitment in the area of Biomechanics allowed to reach the main objective of this dissertation, by the ability to transform the most accessible complicated.

To my parents for all the values and teachings transmitted. For the sacrifices they have made over all these years and above all for the enormous patience in my moments of greater emotional stress.

To my sister for showing me that we all find obstacles in our way but with persistence it is possible to overcome them. Thanks for the advices and protection.

To my great friends and companions, Joana Pinho and António Caires, who on this long journey have shown their friendship and loyalty, never letting me be discouraged. To Joana, a special "thank you" for the dinners and to Antonio for the companionship.

To João Nuno, for the patience even when i arrived tired and the attention that gave to him was little. Thank you for all the words of encouragement and affection.

To my cousin Ana for all the emotional support, encouragement and all the good disposition.

To the staff of the Centro Hospitalar do Porto, especially to D. Augusta, with whom I was fortunate to contact and who gave up precious time. Thank you for all the sympathy and collaboration.

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## RESUMO

A instabilidade patelofemoral é um diagnóstico comum na prática clínica dos Ortopedistas mas continua a ser um desafio, são só pela sua definição ou classificação mas porque não se trata de um problema exclusivo do joelho. Esta pode ser definida como um movimento da rótula para fora da sua normal posição. A maioria dos casos ocorre na população mais jovem, na segunda década de vida, e afeta maioritariamente o sexo feminino. A história natural inclui um longo tempo de limitação funcional e dificuldade em recuperar a função de base por causa da alta recorrência. Neste contexto, torna-se importante fazer uma correta abordagem do doente para encontrar a etiologia da instabilidade.

O diagnóstico é, usualmente, baseado na história clínica, exame físico e imagens radiológicas. É um problema multifatorial e depende da integridade dos tecidos moles que envolvem a rótula, da arquitetura óssea, do alinhamento do membro e interação entre os diferentes grupos musculares. Adicionalmente, a cinemática do tronco, pélvis e anca pode influenciar a cinemática do joelho. Muitos estudos têm sido realizados para avaliar a influência da fraqueza dos músculos da anca na instabilidade patelofemoral. O estudo biomecânico do membro inferior envolve parâmetros antropométricos, cinética, cinemática e dinamómetros permitindo detetar estas anormalidades, que métodos tradicionais de diagnóstico não conseguem avaliar, providenciando evidência para uma avaliação e tratamento corretos.

O propósito deste estudo é salientar a importância da análise biomecânica, especialmente a análise da marcha, nos casos em que a causa da instabilidade não é clarificada através dos métodos correntes. Para atingir este objetivo, o presente estudo baseia-se no caso clínico de uma jovem de 16 anos, com dor bilateral do joelho, mas maioritariamente do joelho esquerdo, que realizou estudo de imagem, análise da marcha e avaliação complementar da cinemática angular durante o agachamento unipodal. Os achados radiológicos demonstraram um desalinhamento rotacional dos membros inferiores, com anteversão exagerada dos colos femorais, rotação interna relativa dos joelhos e torsão tibial externa aumentada. A avaliação por TC do joelho demonstrou uma báscula externa das rótulas superior a 10º, mas com TA-GT's normais e sem *patela alta*. No entanto, a análise biomecânica revelou anormalidades nos movimentos da anca e joelho durante a marcha e agachamento unipodal, com um envolvimento assimétrico, que suportam a hipótese da fraqueza dos músculos da anca esquerda ser o fator desencadeante de maiores queixas desse lado.

## ABSTRACT

Patellofemoral instability is a common diagnosis in orthopedists' clinical practice but still a challenge, not only because of its definition or classification but because it isn't an exclusive knee problem. It can be defined as movement of the patella out of its normal position with respect to the trochlear groove of the femur. The most cases occur in younger population, in the 2nd decade of life, and mainly affects females. The natural history includes a long-term functional limitations and difficult to return to the baseline level of activity because of the high incidence of recurrence. In this context, it is important make a correct assessment of the patient to find the etiology of this instability.

Diagnosis is usually based on clinical history, physical examination and radiological images. This is a multifactorial problem and depends of the integrity of the soft tissues constraints, osseous architecture, limb alignment and interaction between muscle groups. Additionally, trunk, pelvis and hip kinematics may influence the kinematics of the knee and many studies has been made to evaluate the influence of the hip muscle weakness on the patellofemoral stability. A biomechanical study of the lower limb involving the anthropometric parameters, kinetics and kinematics allowing to detect these abnormalities, which traditional diagnostic methods can't evaluate, providing evidence to properly evaluate and treatment.

The purpose of this study is to highlight the importance of biomechanical analysis, especially the gait analysis, in cases in which the cause of the instability is not clear by common clinical evaluation. To accomplish this, the present study is based on a case report of a 16-year-old girl, with bilateral knee pain, specially left knee pain, who underwent imaging studies, clinical gait analysis and a complementary evaluation of the angular kinematics during single leg squat. The radiological findings showed a femoral neck anteversion and a compensatory increased external tibial rotation. CT-scan evaluation of the knee showed a patellar tilt greater than 10º, but with normal TT-TG distance and without *patella alta*. However, biomechanical analysis revealed motion abnormalities of the hip and knee during gait and single leg squat with an asymmetric involvement that supports the hypothesis of weakness of the hip muscles to be a contributor to left knee pain.

## LIST OF FIGURES

## ABBREVIATIONS

**CT:** Computed Tomography

**MPFL:** Medial Patellofemoral Ligament

**MRI:** Magnetic Resonance Imaging

**PFPS:** Patellofemoral Pain Syndrome

**PI:** Patellofemoral Instability

**QoL:** Quality of Life

**RoM –** Range of Motion

**TT-TG distance:** Tibial Tubercle – Trochlear Groove distance

**VMO:** *Vastus Medialis Obliquus*

## SUMMARY

A 16-years-old girl with bilateral knee pain, specially left anterior knee pain, was admitted in Orthopedic service. During the investigation was performed a physical examination, radiographs and CT scan that revealed femoral neck anteversion and a compensatory increased external tibial rotation. To complete the evaluation, instrumented gait analysis techniques were applied during the gait and single leg squat. Abnormalities of the limb segments motion in sagittal, coronal and transverse planes were identified and are consistent with weakness of abductors and external rotators of the hip.

The patient underwent a rehabilitation muscular strengthening program for four months.

This case-report demonstrates how biomechanical analysis of the gait helps to find the knee pain etiology.


## BACKGROUND

Patellofemoral instability (PI) can be defined as movement of the patella out of its normal position. It is a common knee disorder with an incidence of 5.8 per 100.000. [1, 2] The highest incidence of this injury occurring in young athletes in the 2nd decade of life. [2, 3, 4] In general, the patient with PI refers anterior knee pain that cause functional limitation and decreases Quality of Life (QoL).

Although this condition is difficult to treat, there are two type of approaches, conservative and surgical management, and the decision depends on the correct identification of the cause. Current clinical evaluation, in general, includes a detailed anamnesis, physical examination and radiographic imaging. In many cases, this isn't enough to define etiology because, in addition to abnormalities of bones and soft-tissues around the patellofemoral joint, abnormal trunk, pelvis and hip kinematics may cause instability of this joint.

In this report, we demonstrate that biomechanics providing assessment to kinematics and gait analysis can be an important tool and helpful for diagnosis.

## CASE PRESENTATION

A 16-years-old girl was referred to orthopedic observation, due to pain in the left knee during the previous months, with limitations in normal daily activities, without trauma. She told a story of occasionally bilateral knee pain since 8 years old. The pain wasn't persistent

but occurs every day, and doesn't have relation to exercise, although increasing with squatting and stair descending/climbing. There is no personal history of rheumatologic diseases and she denied patellofemoral abnormalities and similar symptoms in family. To evaluate the physical function relating to daily life, sport and recreation she answered KOOS questionnaire that revealed KOOS Pain: 81, KOOS Symptom: 71, KOOS Function in daily living: 94, KOOS Function in Sport/recreation: 25 and KOOS QoL: 38.

On the physical exam, she had neutral lower leg alignment and an increased internal rotation of the hip joints with diminished external rotation, normal RoM (Range of Motion) on knee joints and ankles. She had internal rotated knees, with increased external tibial rotation. The knees were stable, without effusions, with slight discomfort on the sliding of the left patella. She described a pain on the lateral facet. A normal patellar tracking, with a normal patellar tendon inclination was revealed.

On the x-Rays, she had neutral lower leg alignment. On the side view, she presented no trochlear dysplasia, with normal patellar height (Caton index: 1,18). On the axial view at 30º, she had a patella Wiberg type 2.

The CT scan showed a slight lateral deviation of the patella (0.8 cm bilaterally), and normal values to Caton-Deschamps index, TT-TG distance and trochlear angle (Figure 1). With her in ventral position and with knees in extension is clear an increased femoral neck anteversion (right angle with 46º and left with 44º) (Figure 2A) and a compensatory increased external tibial rotation (right and left angles with 40º) (Figure 2C). The femoro-tibial rotation is 18º on the right side and 20º on the left side (Figure 2B). The lateral patellar tilt was of 11º on the right and 14º on the left (Figure 3).

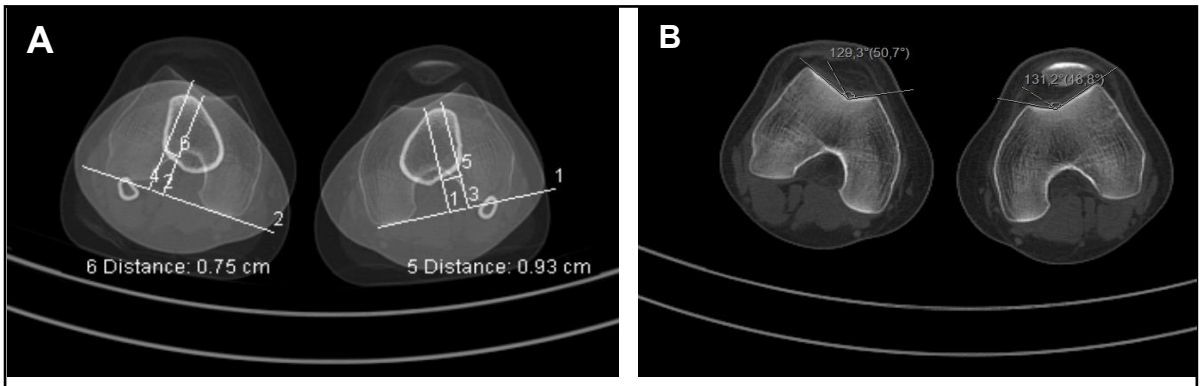


**Figure 1. (A)** TT- TG evaluation (right side: 0,75 cm; left side: 0,93 cm). **B)** Trochlear angle evaluation (right side: 129,3º; left side: 131,2º)

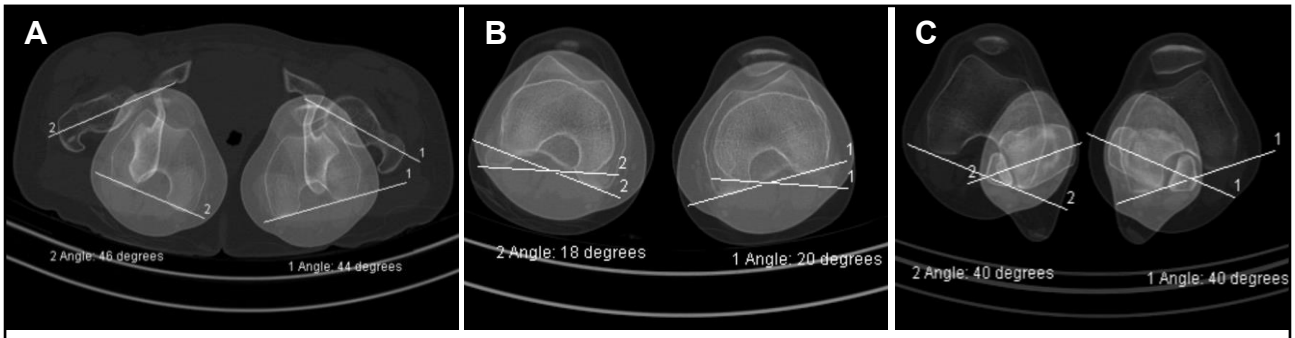


**Figure 2 - CT with lower limb rotational assessment. (A) Femoral neck anteversion** (right side: 46º; left side: 44º)**. (B) Femoro-tibial rotation** (right side: 18º; left side: 20ª). **(C) Tibial external torsion** (right side: 40º; left side: 40º).

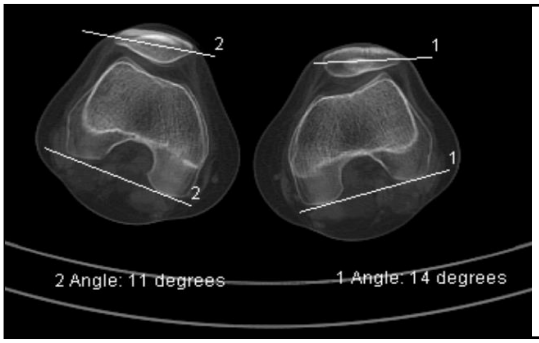


**Figure 3 - Patellar Tilt** (right side: 11º; left side: 14º).

Gait analysis was assessed at the LABIOMEP - Laboratório de Biomecânica do Porto. Retroreflective markers were placed over anatomical landmarks (Figure 4) and movements were recorded by 12 infrared motion capture cameras (Qualisys AB, Sweden). The patient was instructed to walk at a self-selected speed along 10 meters gait corridor over 5 extensiometric (Bertec, USA) and 1 piezoelectric (Kistler, USA) force plates. Gait and squat data was then processed in a biomechanical data analysis software (Visual 3D, C-Motion, USA). The gait kinematics was analyzed in three anatomical structures: pelvis, hip and knee and at least 10 valid data collections were recorder.

**Figure 4 - Positioning of the markers of the conventional whole body model for gait analysis.**

In the analysis of the angular kinematics, in the coronal plane, during the gait cycle, the patient showed an excess of valgus in the left knee (Figure 5C) and an increased internal rotation in the left knee compared to the right in the transverse plane (Figure 5D). The left hip,

during the heel strike, wasn't slightly abducted as would be expect and at the swing phase was excessively adducted (Figure 5B).

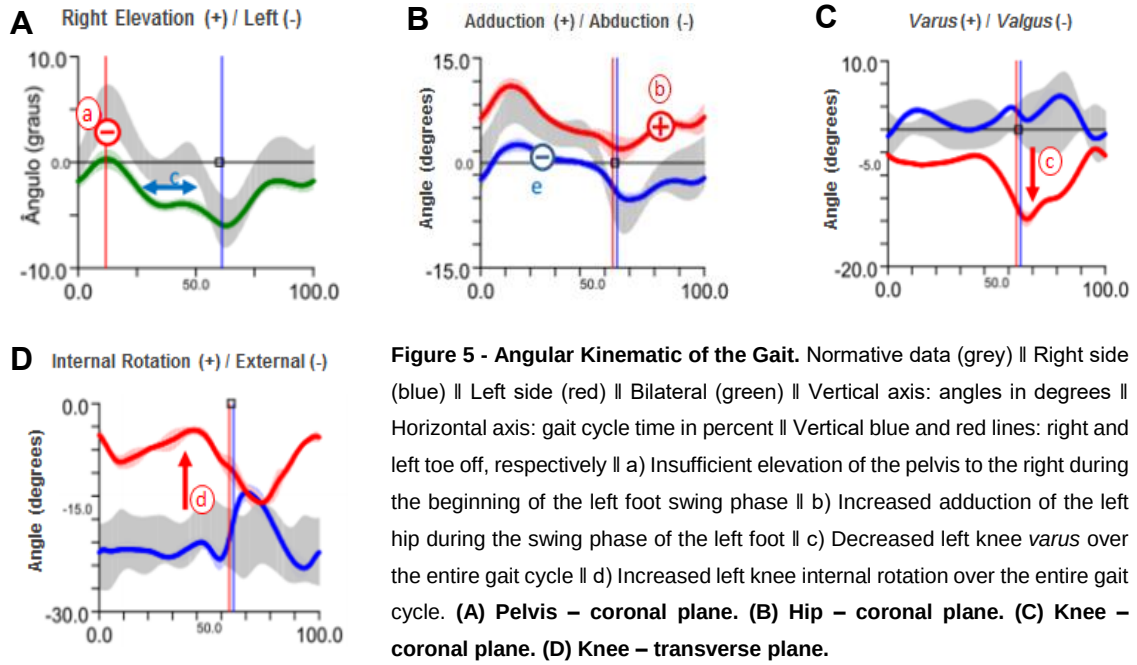


**Figure 5 - Angular Kinematic of the Gait.** Normative data (grey) ‖ Right side (blue) ‖ Left side (red) ‖ Bilateral (green) ‖ Vertical axis: angles in degrees ‖ Horizontal axis: gait cycle time in percent ‖ Vertical blue and red lines: right and left toe off, respectively ‖ a) Insufficient elevation of the pelvis to the right during the beginning of the left foot swing phase ‖ b) Increased adduction of the left hip during the swing phase of the left foot ‖ c) Decreased left knee *varus* over the entire gait cycle ‖ d) Increased left knee internal rotation over the entire gait cycle. **(A) Pelvis – coronal plane. (B) Hip – coronal plane. (C) Knee – coronal plane. (D) Knee – transverse plane.**

As a provocative test for assessment of a neuromuscular disorder of the lower limb, a single leg squat test was performed, using the same *mo-cap* protocol. The patient was asked to stand in a single leg, and perform a squat at the maximum flexion, at a self-chosen velocity.

At the single leg squat the hip of the left side was in increased adduction and increased internal rotation (Figure 6A and 6B, respectively). The left knee was in increased valgus and with less external rotation than the right side (Figure 6C and 6D, respectively).

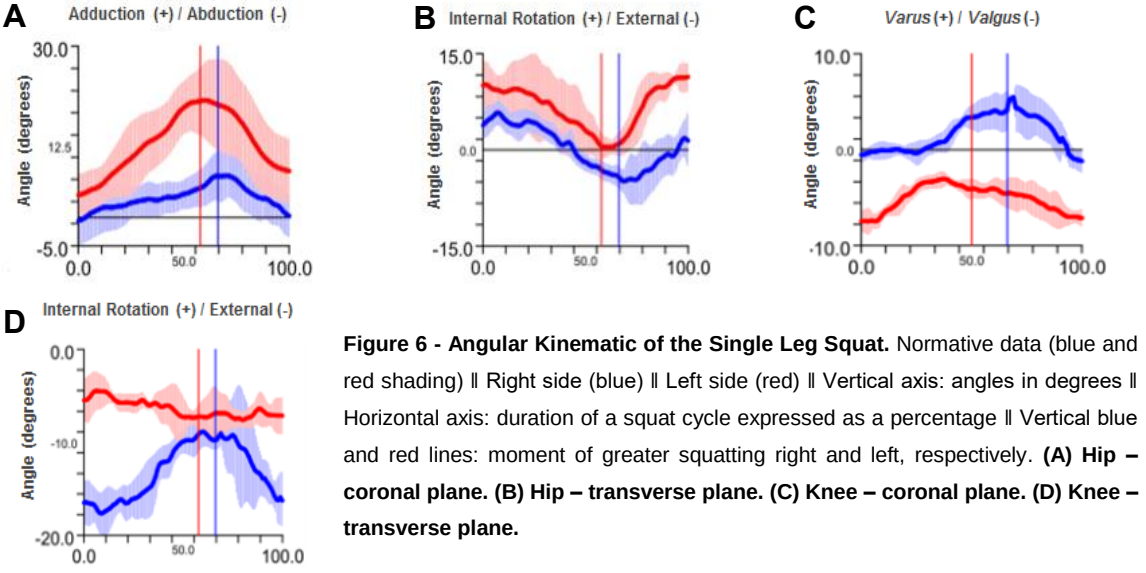


**Figure 6 - Angular Kinematic of the Single Leg Squat.** Normative data (blue and red shading) ‖ Right side (blue) ‖ Left side (red) ‖ Vertical axis: angles in degrees ‖ Horizontal axis: duration of a squat cycle expressed as a percentage ‖ Vertical blue and red lines: moment of greater squatting right and left, respectively. **(A) Hip – coronal plane. (B) Hip – transverse plane. (C) Knee – coronal plane. (D) Knee – transverse plane.**

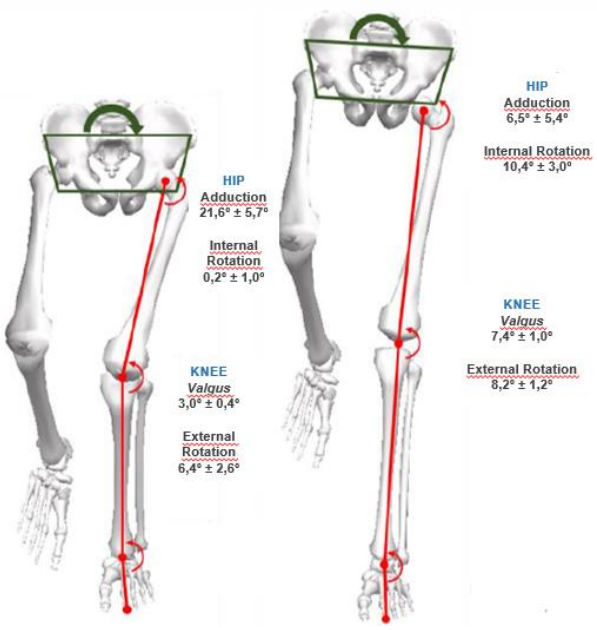


**Figure 7 - Left Single Leg Squat.**

## OUTCOME AND FOLLOW-UP

The patient was referred to a rehabilitation program. She integrated a muscular strengthening plan for four months, with special emphasis in muscle rehabilitation, in CORE muscles and quadriceps strengthening.

On the last observation, *circa* 8 months after going to rehab, she was integrating a pilates class, for continued muscle exercise / strengthening, referring subsidence of the pain in her left knee, with increased subjective strength and referring less restraints to normal day activities.

## DISCUSSION

The Lyonnaise School proposed a classification to patellofemoral instability and nominated three principal factors of instability (patellar height, patellar tilt and TT-TG distance) and secondary features (female sex, *genu recurvatum*, *genu valgum*, pathological femoral/tibial torsion angle and local ligamentous laxity). [2, 5]

Patellofemoral biomechanics is influenced by correct femoral trochlea development and height of the patella. Trochlear dysplasia decreases the bony restraint and the amount of energy required to dislocate, especially in the early degrees of flexion and *patella alta* increases the range at which there is no bony contribution to stability, increasing the risk of

lateral dislocation. [6,7] In addition to osseous abnormalities, soft-tissues around the joint, especially medial patellofemoral ligament (MPFL) and *vastus medialis obliquus* (VMO), may influence joint stability. The Q-angle, is defined as the angle formed by the interaction between two forces acting on the center of the patella. [8, 9, 10, 11] When it is increased, laterally-directed forces on the patella are increased too, suggesting malalignment of the lower limb and predisposing to patellofemoral instability and dislocation. Excessive femoral anteversion and external tibial rotation increase the Q-angle. [12]

In most cases in literature, these factors are evaluated especially by X-Ray and CT-scan despite the lack of consensus on which abnormalities or normal values should be analyzed. X-Ray lateral view in association with CT scan determine trochlear dysplasia using trochlear angle. [5, 13] Patellar height is determined by Caton-Deschamps index [5,13,14,15]. The CT- scan is more useful to evaluate TT-TG distance, patellar tilt with the quadriceps relaxed and contracted and femoral and tibial torsion angles [5, 15, 16]. To complement this study, a MRI can be performed. [5]

The present study demonstrated that alterations in lower limb alignment such as excessive femur anteversion and external rotation of the tibia can be found in association with the morphological abnormalities evidenced by the imaging studies.

The excessive adduction and internal rotation of the hip presented by the patient are consistent with *Nakagawa et a*l [17] who demonstrated that hip adduction and hip internal rotation are greater in subjects with Patellofemoral Pain Syndrome (PFPS). These abnormalities may be the result of rotational changes in the femur [17] and can cause the knee joint center to move medially relative to the foot causing knee valgus, especially hip adduction. Knee valgus may increase the Q-angle that predisposes to lateral patellar tracking.[19]

Femoral adduction and internal rotation are controlled by eccentric contraction of hip abductors and external rotators muscles. [17, 19, 20, 21] Some authors have shown that changes like femoral anteversion are associated to decreased activation of gluteus medius [18] and hip abductors conditioning an abnormal lower limb motion during gait and weight-bearing activities. So, it is possible that the changes evidenced in the gait analysis are cause of the patellofemoral instability presented by the patient and result of neuromuscular alterations, especially weakness of the abductor muscles and external rotators of the hip.

There are previous investigations about factors that can influence patellofemoral stability in the area of biomechanics. *Souza* [22, 23] and *Nakagawa* [17], for example, reported changes in

femur rotation and patellofemoral kinematics and *Souza* [23] studied the influence of muscle activation and hip strength, but none of them used gait analysis. The gait analysis is a poorly used diagnostic tool to evaluate patellofemoral instability, thus there is a shortage of reported cases in which it was used.

The clinical gait analysis evaluates the motion of the various limb segments to find abnormalities such as abnormal rotations of the hip and knee in the transverse and frontal planes presented in this case report and postulate causes. The parameters evaluated are compared with the database of normal individuals. This case report illustrates the information that gait analysis adds to traditional methods of evaluation. It's a useful tool for making clinical decisions and choosing a less invasive and more conservative treatment.

## CONCLUSION

The case report described shows, perfectly, how the diagnosis of patellofemoral instability is difficult because although it is a common lesion and there are different imaging criteria that aid the diagnosis, there is no consensus about which routine should be used in its evaluation.

Anamnesis, physical exam, X-Ray and CT-scan provide analysis of the multiple anatomical and dynamic factors described by the Lyonnaise School and which are the basis of the development of instability.

With the evolution of research in the field of biomechanics other anomalies that may influence the kinematics of the patellofemoral joint have been described. When information obtained through the common clinical routine is not sufficient to obtain a diagnostic conclusion or to determine the mechanisms of injury, an additional evaluation is needed. The diagnostic tool discussed in the present case report allows us to obtain objective information, mainly related to the kinematics of the hip and knee. Thus, it is possible to postulate primary and secondary causes of the changes presented by the patient.

Nowadays, the less invasive and cost-effective treatment is increasingly favored. Studying the potential of biomechanical gait analysis will allow an evolution in the approach to patellofemoral pathology as well as reduce costs associated with treatment and increase patients' quality of life.

## LEARNING POINTS

- Patellofemoral instability is one of the most common injury in orthopaedics consultation. The multifactorial etiology makes workup diagnosis complex.
- The CT scan can be useful in detecting abnormalities in known anatomic parameters, thus guiding us in establishing the cause of the pain.
- Not all the patellofemoral pain can be justified by morphological abnormalities; some are caused by altered lower limb kinematics, due to neuromuscular disorders.
- This case shows the importance of biomechanical analysis of the gait on the clinical evaluation of patellofemoral instability, especially when the etiology involves abnormal hip and knee kinematics.

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